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Efficient gesture recognition algorithm based on Continuous Dynamic Programming

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Introduction

It would be helpful, in situations in which humans and robots work in cooperation with one another, for the robots to be able to understand the humans' motions and help appropriately. To make this possible, it is important to perceive human motion in video images as sequences of individual movements. A number of techniques have been proposed for the recognition of human movements [1][2], and we ourselves have presented a gesture-recognition method focusing on real-time applicability[3]. Features of our model are:

- Use temporal edges as a feature
- To use Continuous Dynamic Programming (CDP) for matching against the models [4]

The temporal edges are obtained by passing the input from a CCD camera through temporal-differencing, spatial-reduction, temporal-averaging, and logarithmic processing, producing what we call a "feature-image". All of these processes are comparatively simple, and are thus well suited to real-time recognition systems. CDP matching is one a group of methods known as "spotting" techniques, and is capable of producing a result for each frame as it is processed. Also, because the amount of matching time it is requires is only proportional to the total number of frames in a model, it is commonly used in the field of voice recognition. For image recognition, however, for every unit of time, the number of dimensional distances that have to be calculated for feature-images is equal to the total number of frames —and this poses a problem when constructing systems capable of recognizing large-scale models.

- clustering using the k-means method, and
- reducing computation-time by parallel processing.

Clustering

The diverse gestures made by human beings can be thought up of as being constructed from a set of simple elemental movements. It can be effective, particularly for systems using large-scale models, to classify these movements into categories, and then to express gestures using category numbers. Also, if the number of categories is

Table 1: Recognition-ratios Using Clustering (%)

Feature-image	98
32Clusters	83
64Clusters	95

smaller than the total number of models, this can be a useful technique for improving speed, since the number of times distance between feature-images into categories, and then conducted recognition tests.

Recognition Testing

The gestures that served as the objects of recognition consisted of four types of motions:(1)putting down a book, (2)opening the book, (3)turning to the next page, (4)returning to the previous page, (5)closing the book, and (6)holding the book. These were filmed from seven different directions fifteen degrees apart, centered on the position directly in front of the experimental subject, for a total of 42 models. We then checked the recognition-ratio using the same human subject, wearing the same clothes, against the same background, for all 6 motions $\times$ 7directions (Table 1). Our input-image size was 256$\times$256, the feature-image size was 16$\times$16, and the temporal-averaging constant was three frames. This test showed that, assuming that one selects an appropriate number of clusters, there is hardly any difference from the case in which the distance calculations are made using the feature-image directly.

Calculating Time

Next, we conducted comparisons of calculating time between the case in which the feature-images were used and that in which 64 clusters were used(Table2). The input video was 495 frames long, and the total number of frames in the standard-patterns was 967.
We found that the time required for distance calculations was thirteen times faster in the case using k-means.

Parallel Processing

For CDP matching, we calculate the local dis-

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[Abstract] [PDF Full-Text (796 KB)] **IEEE CNF**

Table 2: Calculation Time (s)

	Feature	64Clusters
Local-distance Calculation	56.2	0.2
Categorization	0.0	4.2
Total	56.2	4.4

tance $d(t,\tau)$ between input frame t and standard-pattern frame τ, for all of the standard-patterns. Then, using these results, we progressively calculate the cumulative distance $S(t,\tau)$ for each pattern, as follows:

$$S(-1,\tau) = S(0,\tau) = \infty \quad (1 \le \tau \le T) \qquad (1)$$

$$S(t,1) = 3 \cdot d(t,1) \qquad (2)$$

$$S(t,2) = \min \begin{cases} S(t-2,1) + 2 \cdot d(t-1,2) + d(t,2) \\ S(t-1,1) + 3 \cdot d(t,2) \\ S(t,1) + 3 \cdot d(t,2) \end{cases} \qquad (3)$$

$$S(t,\tau) = \min \begin{cases} S(t-2,\tau-1) + 2 \cdot d(t-1,\tau) + d(t,\tau) \\ S(t-1,\tau-1) + 3 \cdot d(t,\tau) \\ S(t-1,\tau-2) + 3 \cdot d(t,\tau-1) + 3 \cdot d(t,\tau) \end{cases} \quad (3 \le \tau \le T) \qquad (4)$$

The cumulative distance S can be calculated in parallel for each frame of each standard-pattern. Accordingly, we converted the algorithms for parallel processing and ran calculating-time tests, using a CRAY CS6400 as our computer. At present, the CS6400 at RWCP has 12 CPU's. Since one of these, however, is used ad the system controller, we ran our comparison on the remaining 11 CPUs. The result showed a calculation speed 4.2 times faster than on a 1-CPU system.

The Real-time Gesture-spotting System

Based on the results of the experiments we have conducted up to now, we have created a system that recognizes gestures in real-time(30 times per second). The series of images coming from the CCD camera is passed as input into an off-the-shelf general-purpose image-processing board(IMAGING TECHNOLOGY Series 150/40). This board runs edge-extractions, spatial reduction, and temporal averaging on the images. All of the feature-extraction parameters are the same as the values we used in the test system. The memory on

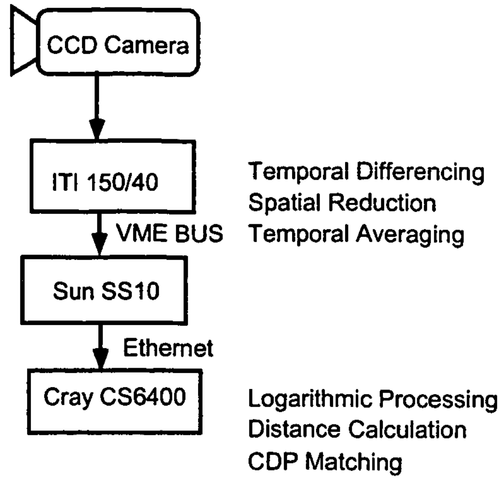

Figure 1: System Configuration

the image-processing board can be accessed from the host workstation, a Sun SS10. The feature-images produced in that on-board memory are than transferred via socket-communication to the CS6400, which conducts the CDP and the logarithmic processing (Fig.1). We have verified that our system can work in real time with 42 standard-patterns(containing 967 frames).

Conclusion

We have constructed a system with which it is possible to perform matching with a large number of models in real time. In the future, we plan to develop more efficient ways of representing gestures, to construct a noise-robust system, and to raise the efficiency way of our parallel processing.

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